

neck; posteriorly the thin edges are turned over the back. Creamy white in colour. The posterior is twice as large as the anterior sucker, is quite circular, prominent, 1 millim. in diameter; it is placed just anteriorly to the middle of the ventral surface.

The pharynx is large, and cæca are developed from the hinder halves only of the two branches of the intestine.

The eggs are scattered abundantly through all but the anterior region of the body, and call to mind the figure given by Olfers of *Distomum folium*, from which species (found in the urinary bladder of *Esox lucius*) this may be at once distinguished by the absence of a neck; the eggs measure 0·1065 millim. in length, and ·07 millim. in breadth.

The length of the whole body is 5·5 millim., and its greatest breadth 3 millim.

The specimen of *Halosaurus* from which this fluke was taken was dredged off Cape St. Vincent at a depth of 1090 fathoms.

XV.—*On some Points in the Morphology and Classification of the Saleniidæ, Agassiz.* By Prof. P. MARTIN DUNCAN, M.B., F.R.S., F.L.S., and W. PERCY SLADEN, F.G.S., Sec. L.S.

CONTENTS.

The Sur-anal or Dorso-central Plate and its Homologies; the Periproctal Plates. Some new Points about the Genera *Acosalenia*, *Peltastes*, and *Salenia*, and a reconsideration of the Classificatory Value of the Genera *Pseudosalenia*, *Hyposalenia*, *Goniophorus*, and *Heterosalenia*.

I. *The Sur-anal Plate.*

When the genus *Salenia* is mentioned, or the family of the Saleniidæ, to which it belongs, one of the most important structures inevitably arises in the mind—the sur-anal plate, with its many synonyms. The term has been an unfortunate one, although nothing could have been clearer than the meaning which its author desired to give it. L. Agassiz wrote, in his *Monogr. d'Échinod. Viv. et Foss.*, 1838, livr. i. p. 6:—"The genus *Salenia*, restricted within the limits now assigned, is characterized by an odd plate placed in the midst of the oviducal apparatus, which I shall call the sur-anal, which, consequent on its position *vis-à-vis* to the anal aperture, always renders the anus excentric."

L. Agassiz did not mean to imply that the plate was on the anus, although not having seen a recent *Salenia* he did not distinguish between the orifice of the anal tube—the anus proper—and the periproctal ring, which gives attachment to the membrane which has the anal passage in it. He meant *vis-à-vis* to the periproctal ring. The name of the plate in question has been subjected to several alterations, and its morphological meaning and homologies have been repeatedly discussed.

Alex. Agassiz* in 1864 pointed out that in young examples of *Strongylocentrotus* the central area of the apical or abactinal system is closed by a single large circular plate which occupies the whole of the space within the ring of the genital or basal plates. During the succeeding stages of growth this plate does not increase in size, but is more or less resorbed. Numerous supplementary plates are subsequently formed on the periproctal membrane, from which, at the adult stage, the original primary plate is often scarcely distinguishable.

The same naturalist, when studying, at a later date, a recent *Salenia*, showed that the sur-anal plate (called by him sub-anal) is the homologue of the first-formed central plate of young Echini, and remarked † that “the abactinal system of *Salenia* is entirely homologous with the abactinal system of the other Echinoids,” the original central plate retaining a greater preponderance than is the case in other genera.

Lovén‡ is very definite in his views regarding the homology of the sur-anal plate of *Salenia* and the primary central abactinal plate of young Echinidæ, and he terms both the “central disk” of the dorso-central system.

In his remarks upon the apical system of *Strongylocentrotus*, after referring to the discoveries of Alex. Agassiz, he observes that the “central disk” is developed before the anal opening of the intestinal canal is formed, and that the arrangement of the parts is such that the opening cannot occur, except after the putting aside or partial resorption of the disk. Consequently the central disk, far from being a simple protecting appendage of the anal opening, must be considered as a “*pièce à elle*” and independent—an integral part of the dorso-central system having a special morphological value. He then proceeds to state that “*Salenia* furnishes a conclusive proof of this, as Mr. Alex. Agassiz has remarked. In this genus the

* “On the Embryology of Echinoderms,” Mem. Amer. Acad. 1864, vol. ix. p. 12.

† ‘Revision of the Echini,’ p. 259.

‡ ‘Études sur les Echinoïdées,’ p. 69 *et seq.*

central disk, far from having an ephemeral existence as in the Echinidæ, is permanent, occurring throughout the lifetime of an individual as a persistent and solid plate, growing with the other pieces of the skeleton, and filling the central space with its lamina, which is perfectly pentagonal. When the anal orifice opens out, it becomes partially eroded at the edge by resorption." He concludes:—"But the central disk always retains, in a perfectly recognizable manner, its primitive pentagonal form, and it is evident that it is not a sur-anal or supplementary plate occurring in *Salenia* and its allies, but is a normal part of the skeleton which persists throughout the life of the animal."

Herbert Carpenter, following A. Agassiz and Lovén, homologizes the sur-anal plate of *Salenia* with the primary central plate of the abactinal system of *Echinus*; and furthermore, in his instructive essay "On the Oral and Apical Systems of Echinoderms" (Quart. Journ. Micr. Sci. n. s. vol. xviii.), he establishes, on logical grounds, the true homology of a corresponding plate in the Crinoidea, Asteroidea, and Ophiuroidea.

Alex. Agassiz, with his characteristic generosity, sent to one of us a very fine and large specimen of *Salenia Pattersoni*, A. Ag., in spirit; and its study has enabled us thoroughly to appreciate our friend's admirable descriptions of the species in the "Report on the Echini of the 'Blake' Expedition," p. 13, pls. iv. and v.

In this specimen the sur-anal plate is large and as well defined as in any fossil *Salenia*; it is, as is usual in *Salenie*, incomplete in the right posterior angle, and this part is, as usual, eroded more or less by the periproct. The plate forms a part of the ring of the periproct. The periproct is large, and has a rather stout membrane, which is attached to the edge of the ring formed by the sur-anal and the basals 1 and 5; the anal orifice is central and the space between it and the ring is covered with well-formed plates, which are large near the ring and smaller and more numerous near the orifice, and most carry stunted spines. (See also A. Agassiz, 'Blake' Echini, pl. iv. fig. 18.)

These plates of the periproctal membrane, which become more numerous with age, are the homologues of the similarly placed plates of *Echinus*, *Strongylocentrotus*, &c., and they bear the same relation to the orifice of the anus within the periproctal ring.

Alex. Agassiz examined the young forms of *Salenia* dredged by the 'Blake' with the expectation that they might "throw some light on the formation of the sur-anal plate and its homo-

logy with the single large anal plate of the early stages of young Echini belonging to other families" ('Blake' Echini, p. 18). He states:—"But in all the young stages, even when not measuring more than 1.5 millim. in diameter, the arrangement of the plates of the abactinal system does not differ from that of the older specimens, the sur-anal plate being only proportionally somewhat smaller." He states that, in the youngest stage of *Salenia* examined, the anal system is distinctly pentagonal and covered by eight large triangular plates.

From the foregoing observations it may be deduced that the central plate of the abactinal system is a primary embryonic plate, which in *Salenia* and its allies grows *pari passu* with the growth of the test, and by this means remains contingent through life, along the greater portion of its circumference, with the basal plates. It thus lies outside the periproctal ring, of the margin of which it contributes to form a part, and the supplementary plates which are formed on the periproctal membrane are prevented from inserting themselves between it and the neighbouring basal plates.

In the Echinidæ, on the other hand, the primary central plate does not grow as the test grows, but may even be diminished by a greater or less amount of resorption. Consequently it always lies inside the periproctal ring, and the supplementary plates which are formed upon the periproctal membrane insert themselves between the rudiments of the primary central plate and the basal plates; and, finally, in the adult stage, the primary central plate may have become so insignificant as to be scarcely distinguishable from the supplementary or so-called "anal" plates. Although thus masked and diminished in size, the significance of the plate from a phylogenetic point of view is in no way lessened.

The persistence of a sur-anal plate ever since the age of the Lias (an age not greatly removed from that in which the Perischoechinidæ alone were represented) in *Acrosalenia*, *Peltastes*, and finally in *Salenia*, shows that the plate has a very great significance, and this has impressed every naturalist who has studied the structural resemblances of the great groups of the Echinodermata.

As a sequel to these remarks upon the sur-anal plate, it is extremely desirable to fix its proper terminology, for neither of the names given to it by the elder Agassiz, and by A. Agassiz, nor that suggested by Lovén is free from objection. Sur-anal, sub-anal, and central plate bring the structure too much into relation with the anus, with which it has really nothing to do.

The term sur-anal should imply a plate which is situated upon the anus, and in such a sense the primary central plate of young Echinidæ might in its primitive position, before the actual existence of an anal aperture, be styled, with some reservation, a sur-anal. But to its ultimate position the term is totally inapplicable. This fact is still more conspicuous in the case of the sur-anal plate of L. Agassiz in *Salenia*, which, lying in front of the periproct, outside the ring of which it forms a part, has nothing to do with the anal orifice.

As Lovén has called the apical or abactinal system the "dorso-central system," an appropriate term for the plate in question will be the "dorso-central plate," which also has the advantage of having been already employed by Herbert Carpenter and other writers.

The homology of the dorso-central plate has been the subject of careful study by A. Agassiz, Lovén, and Herbert Carpenter, and some differences of interpretation exist; but, in our opinion, the forcible arguments of the last-named naturalist carry conviction. The case has been so clearly and fully stated by him that we consider it unnecessary to recapitulate the evidence upon which his deductions are founded, and that it will be held sufficient for our present purpose to state that we agree with him in considering that the dorso-central plate of Echinoids, Asterids, and Ophiurids is homologous with the radical plate or root-disk at the extremity of the stem of the Pentacrinoid larva.

To the supplementary plates developed on the periproctal membrane and surrounding the aperture of the anus the name of "anal plates" has been given; but we think that "periproctal plates" would be a preferable term, as a means of avoiding any chance of confounding them homologically with the definitely-placed anal plates of the older Crinoids.

These supplementary or periproctal plates are well seen in the Cidaridæ, Saleniidæ, Diadematidæ, Echinidæ, and in fact more or less definitely in all the Echinoidea. They show a considerable amount of variability in their character and disposition. In some forms they are present in the younger stages as large solitary plates with more or less curved outlines, which become resorbed and added to in number, until a collection of various sized plates surrounds the anal orifice, the largest plates being nearest the ring of the periproct. In other forms the periproctal plates may persist as four, five, or more triangular pieces having their bases attached by ligament to the inner part of the periproctal ring, their free angle surrounding and assisting in closing, when

required, the anal orifice. In the irregular Echinoidea the plates above the anus are often the largest.

II. On the Genera of Saleniidæ.

Genus ACROSALENIA, Agass.

The structures of the apical system of some of the species of this genus are more readily comparable with those of the other great groups of the Echinoidea than those of *Salenia*. Thus *Acrosalenia spinosa*, Agass., from the Inferior Oolite, presents a symmetrical pentagonal dorso-central plate, which is in the polar axis of the test and in the antero-posterior axis of the apical system; it is placed within the antero-lateral basals, to which it is fixed by suture. It is limited posteriorly by the periproct, which curves its posterior border. The plate is ornamented with small tubercles which carried spines, its construction resembles that of the basals, and it was immovable. The periproct is thrown backwards, and owing to the fixity of the dorso-central plate the posterior basal (5) became small and the radials I. and V. came within the periproctal ring. The anal (periproctal) plates are not preserved, but they doubtless surrounded the anal aperture within the periproct.

In *Acrosalenia decorata* (Haime, sp.), Wright, from the Corallian, the dorso-central plate is in its normal position, and occasionally it is perfectly hexagonal and in no way eroded for the periproct (Wright, Monogr. Brit. Foss. Echin. Oolitic Form., Pal. Soc. 1856, pl. xvii. fig. 1*f*). Behind this plate are five or six others, and then comes what might be well considered to be the periproctal ring; but from the position of the radial plates it would appear that the smaller plates in contact with those behind the dorso-central plate may be within the periproct. Almost as good an instance of the preservation of a geometrical dorso-central plate without any notching for the periproct is seen in Bone's good figure on the same plate, fig. 1*g*, and there are no supplementary plates, but a large periproct. Of the independence of the dorso-central in this species there can be no doubt.

Acrosalenia Loweana, Wright, has small additional plates which separate the dorso-central from the postero-lateral basals, but it would seem that they are really supplementary plates. In *Acrosalenia Wiltoni*, Wright, there is a row of plates between the dorso-central and the large periproct, and they are supplementary plates (Wright, *op. cit.* pl. xvii. fig. 5).

The entrance of the posterior radial plates into the peri-

proctal ring is usual in these species, and in some others, such as *Acrosalenia pustulata*, Forbes, in which the dorso-central is accompanied by supplementary plates, the anterior radial plate (III.) may enter the space between the antero-lateral basals. All this persistence of a dorso-central, and its occasional association with supplementary plates, and its growth in relation to the other parts of the apical system, was accompanied by movement outwards of basal plates and inward movement of radials.

One of the later *Acrosalenia* (*A. angularis*) varies in the nature of the plates accompanying the dorso-central, as may be noticed in the figure given by Lovén ('On *Pourtalesia*,' 1883, p. 66, and de Loriol, Mém. Soc. Pal. Suisse, vol. xii. 1^{er} supp. à l'Échin. Helv. 1885, pl. i. fig. 4). This species is as interesting as the last of the *Acrosalenia* (*A. miranda*, Cott., Péron, & Gauth., Éch. Foss. de l'Algér., 2^e part. p. 86). This Neocomian species has the dorso-central large, central, and separated from the periproct by some small periproctal plates.

It appears that in *Acrosalenia* some species have a perfect dorso-central with an angular posterior part; others have it eroded for the periproctal ring; others have small supplementary plates between it and the ring or elsewhere.

There is a very important character which is present in all the species of *Acrosalenia*; it refers to the so-called cuts or branchial grooves at the peristome. These grooves and indentations of the peristome are very well developed and are large for the size of the test; they pass up on the outside for a short distance along the line of the interradio-ambulacral sutures, and each one is bounded by a raised rim or edge. Although Desor stated to the contrary, these grooves are well seen in good specimens, and give a marked character to the genus. The corresponding parts are small in the genus *Salenia*, and it is now known that the branchiæ are small in the recent species. It will be observed that in this character *Acrosalenia* departs more from the type of the Cidaridæ than *Salenia*, and yet the first-named genus is the older one.

The Perignathic Girdle.—This structure may be seen after careful removal of the matrix when it is soft. The ridges are broad and low, and the processes are moderately tall and slender; they do not usually arch over the ambulacra, but they may join at their free ends and thus arch in some specimens. The type is not that of the Cidaridæ, but of the other Endocyclica (see Journ. Linn. Soc., Zool. vol. xix. p. 179).

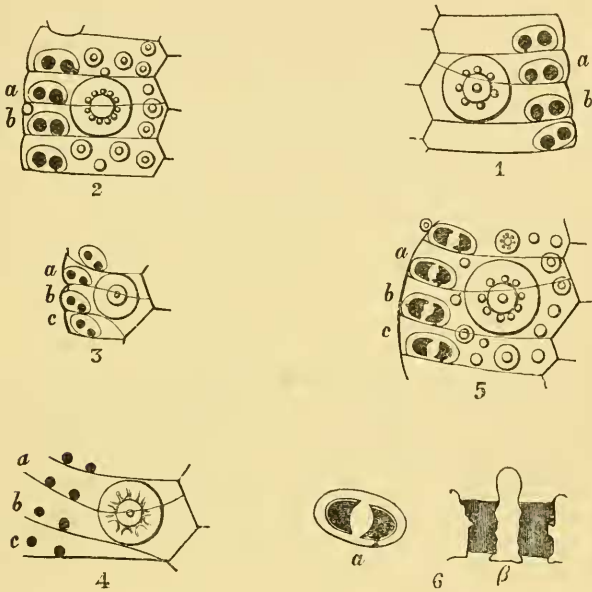
The Ambulacral Plates.—One of the reasons why the Saleniidæ have been considered to be closely allied to the Cidaridæ is that the ambulacral plates in both groups are

believed to be low primaries, each with a pair of pores; it has also been stated that in neither of the types is there any biserial arrangement of the pairs near to the peristome. But the crowding out of pairs and the biserial arrangement has been described in every species of *Acrosalenia*. The construction of the ambulacral plates has, however, not hitherto been described, and it is very interesting and important in classification.

Desor is only partly correct in his statement that the pairs of pores in *Acrosalenia* are "simple," meaning that there was a pair for each plate and that there were no compound plates. The ambulacral plates are simple for varying distances from the radial plates, and are long low primaries, each of course with a pair of pores, the peripodium being well developed and the nodule between the pores of a pair often being broad and high.

In *Acrosalenia spinosa* the straight vertical row of pairs is interfered with not far above the ambitus, and three or four pairs of pores begin to be in slight curves, and this condition increases with the dimensions of the ambulacral tubercles. It is easy to trace, in weathered specimens, that there are compound plates in that part of the ambulacrum, and extending thence to the peristome. The plates have been originally primaries, and have been compressed from above downwards and in the contrary direction by the succession of plates and the growth of the comparatively large ambulacral tubercles. The succession is a simple primary followed by a compound plate made up of two primaries formed into a geometrical plate, the upper one, *a*, being the smaller and having its adoral sutural line passing from the adoral pore obliquely upwards and towards the median ambulacral suture, and crossing the tubercle on its aboral shoulder (fig. 1). The other or adoral primary, *b*, is larger, especially at the median suture of the ambulacrum, the greater part of which is formed by it. The two primaries constitute a compound plate and are formed into a geometrical figure. Then comes a single primary without a large tubercle, and this plate is broad, low, and about one half of the height of the compound plate above it. A compound plate comes next, and it closely resembles the one above; but the suture may be more transverse, and it is followed in its turn by a simple primary (fig. 2). This succession is repeated several times until close to the peristome, where crowding and decided curving in arcs of the peripodia occur (fig. 3). But the crowding (fig. 3) is not after the type of the Triplechinidæ, for instead of there being compound plates with three components, only two primaries (*a* and *b*) occur in a compound

plate, and the adoral peripodium, *b*, is close to the interradius. The lowest peripodium of the apparent triplet, *c*, covers nearly the whole of its plate, which is crowded out from and does not reach the median ambulacral suture; it does not form part of a compound plate, and it is a demi-plate (single). The crowding of the plates at the very edge of the peristome is still greater and the sutures are obliterated in the specimens; but it is evident that there are demi-plates there. In a specimen in the British Museum (fig. 4) there is a triple com-



Ambulacral plates of *Acrosalenia*; much of the ornamentation is omitted.

pound plate between the ambitus and the position of the commencing crowding of the pairs, in which pressure has united the usual two primaries, *a* and *b*, and also an adorally placed primary, *c*. The cause relates to the growth of a tubercle, and the adoral primary (*c*) has been so pressed from above downwards that it barely reaches the median ambulacral suture and is almost a demi-plate. This is the first step to the more decided crowding and deformation which are seen nearer the peristome.

It has been stated by more than one author that when the apical disk of *Acrosalenia hemicydaroides* is absent the specimens cannot be distinguished from those of a *Hemicydaris* deprived of that system.

But there are several important structural distinctions between the species of the two genera. For instance, the branchial cuts of the *Acrosalenia* are large and those of *Hemicydaris* are small; the great tubercles of *Hemicydaris* cover three plates arranged in a compound geometrical plate, and this is never the case in the *Acrosalenia*, which has the tubercle followed by a large granule in vertical succession, the tubercle being in relation with two plates of a compound one and the granule being upon a small, low, separate primary. The construction of the ambulacral plates differs completely in the two genera, and if the special arrangement of the great compound plates of a *Hemicydaris* described in Quart. Journ. Geol. Soc. vol. xli. p. 438, figs. 13, 14, 15, 16, is compared with similarly placed ones of *A. hemicydaroides* (fig. 5), the distinction becomes obvious; there are three component plates in the one and but two in the other species. There are no instances of compound plates made up of four plates in *A. hemicydaroides* as in *Hemicydaris*, and the slope of the plates and the directions of the sutures differ in the two forms. Near the peristome of *A. hemicydaroides* the crowding produces triplets, and they are remarkable, for, unlike the arrangement in *A. spinosa*, the adoral primary is long and low, the median primary is large at the median line, and the aboral primary is almost a demi-plate. The adoral suture of the last-named plate is much curved. There is a certain amount of resemblance in the peripodia of the two sets of forms, but those of the *Acrosalenia* (figs. 6 *a* and *β*) are characterized by a very prominent interporous knob which stands up well beyond the level of the test.

Acrosalenia pustulata, Forbes, was carefully studied by Wright (*op. cit.* p. 242, pl. xvi. figs. 2 *a-g*), who remarks upon its variability in specimens of the same dimensions, and of course in those of different ages. But Wright's specimens do not appear to have enabled him to give a figure of the apical disk which could be correct, and his descriptions of the structure are, naturally, not positive. His studies regarding the variability of the tests were directed to explain Forbes's seeming inaccuracy about the separate condition of the scrobicules of the large interradian tubercles and about the median area only having two rows of tubercles. Wright showed that Forbes's specimen was immature. In consequence of this perfectly correct view, Wright gave a new diagnosis of

the species (*op. cit.* p. 242). This description, made thirty-one years ago, readily enabled the species to be distinguished from all *Acrosalenia* except *A. Wiltoni*, Wright, and *A. Lamarcki*, Desor. If the figure given by Desor ('Synopsis,' pl. x. fig. 2) of *A. Lamarcki* be compared with specimens of *A. Wiltoni*, Wright, the distinction is evident. The shape differs and the scrobicules of the great tubercles are separated by two lines of granules; the width of the median ambulacral zone is less than that of *A. Wiltoni* and *A. pustulata*. The small peristome and small apical system distinguish the foreign species from *A. pustulata*. The distinction between *A. pustulata* and *A. Wiltoni* is, however, not great, and if the figures given by Wright (*op. cit.* pl. xvi. figs. 2 *a-f* and 3 *a-e*) be examined critically, the whole of the specific differentiations rest upon the dimensions of the peristome. We cannot agree to the correctness of Wright's fig. 2 *d*, pl. xvi., on which much depends. The whole of the pairs of pores on the line towards the interradium drawn are wrongly placed, and the adoral pores are made aboral; the arrangement of the tubercles and the granules between them and in the interporiferous area is not consistent with fact. There are really crowded granules between the tubercles, and at least three vertical sets of granules in the median area.

The width of the ambulacra is, however, well shown in the figure, and it is equal to that of a coronal plate bearing a large interradial tubercle, that is, the breadth of one half of an interradium.

Thus the statement made by Wright that the ambulacra of *A. pustulata* are narrow is contradicted. The truth is that they are wide for the size of the test and not quite so wide as they are drawn.

Again, in fig. 2 *d*, all the plates in the ambulacra are compound ones; and this is not correct, for the arrangement is exactly like that of the species already noticed in this communication.

The relative size of the apical disk and the position of the radials, and the number of accessory plates and the nature of the dorso-central, depend largely on growth, the adults and the half-grown differing considerably in these matters.

The youngest specimen we have examined, which is sufficiently well preserved to afford good results on examination, is 18 millim. high and 9 broad. The apical disk is on the whole tumid and raised above the test. The anterior basals are larger than the postero-lateral; basal 5 is well developed, is about one third of the size of a postero-lateral, is angular without and curved within, and has a single row of minute

tubercles parallel to the curved edge. The radial plates are broad adorally and the optic pore is in the adoral edge; the posterior radials enter the ring of the periproct and are elongate. The radials II., III., and IV. do not enter the periproctal ring. A well-defined, small, pentagonal, dorso-central plate is placed in the antero-posterior line of the test and bounds the periproct in front; its sides are not in contact with basals 1 and 4. A small supplementary plate is on each side of the dorso-central, and these side-plates are not symmetrical; they and the dorso-central plate bound the periproct anteriorly.

In examining a large series of specimens of the different species of *Acrosalenia* it becomes evident that perforate and imperforate tubercles may occur, although the perforate condition is by far the commonest. The entrance of a radial plate between the basals, besides the usual radials I. and V. is seen in some specimens of the species even in which the majority of forms have not this character. It follows that the position of the radials, all other characters being the same, is not sufficient to alter the specific character, much less the generic. The position of the radials and the perforate or contrary condition of the tubercles will be noticed as of no great importance in some types which are about to be described.

Genus ACROSALENIA, Agassiz, 1840, amended.

Test moderate in size, depressed, tumid at the circular and rarely pentagonal ambitus, rounded above, flatter actinally. Apical system rather large; four lateral basals large, and the posterior smallest and differing in shape. A dorso-central plate in the antero-posterior axis of the system, in contact with the four larger basals and anterior to the periproct. Supplementary plates to the dorso-central may occur. Posterior radials enter the ring of the periproct, rarely a radial separating the antero-lateral and postero-lateral basals more or less. Periproct large and posterior. Ambulacra moderate or narrow, with primary plates near the apical system and with compound plates near the ambitus and actinally. Compound plates of two united primaries with rare demi-plates, except near the peristome. Pairs crowded and biserial near the peristome, from the presence of demi-plates. Tubercles of the interradia largest, perforate and crenulate; those of the ambulacra much smaller or only like large granules. Peristome large, decagonal, with well-developed branchial grooves with raised edges. Perignathic girdle with low ridges and slender pro-

cesses sometimes uniting. Spines large and small, the former striated longitudinally, or plain, and often not quite circular in transverse section; smaller spines striated.

Distribution. Fossil: Lias to Neocomian, England, Europe, and North Africa.

It will have been observed that *Acrosalenia* is the oldest of the Saleniidæ and that its species are more complex than those of any other genus of the family. The frequent perfection of the dorso-central plate, the existence of compound plates in the ambulacra, the well-developed branchial cuts, and the ridges and processes of the perignathic girdle separate the genus from the Cidaridæ, and it is more distinct from that family than are the genera *Peltastes* and *Salenia*.

These last-named genera can hardly have had an Acrosalenian ancestry. *Acrosalenia* became extinct before *Salenia* attained much importance, but there was a *Peltastes* with Acrosalenian affinities in the time of the Oolite.

Genus PELTASTES, Agass.

The oldest species of the *Peltastes*-group is a true *Peltastes* in all the characters but one, and that is remarkable, for the primary tubercles of the interradia are perforate as well as crenulated.

There are several specimens of this species from the Corallian of Wurtemberg, and the locality Nattheim, in the British Museum, and they correspond with *Acrosalenia interpunctata*, Quenst. (Petref. p. 576 (old edition), pl. xlix. figs. 5 and 6). The test is depressed and the apical system is large; the basals are large, the posterior unusually so, and the dorso-central is comparatively small. The periproct is directly posterior. The ambulacra are narrow, wavy, and have two rows of small secondary tubercles, so closely placed that nothing is seen between them along the median suture. The pores are moderately numerous, in simple series, and there is a pair to each plate, and there are no primary plates joined to form compound plates, but every plate is separate, as in *Peltastes* and *Salenia*. Neither the apical nor the ambulacral development is that of *Acrosalenia*.

The primary tubercles of the interradia are large and have perforate mamelons and crenulated bases. The branchial cuts are small. Quenstedt noticed its many-sided character, and it is now necessary to place the form as follows:—

Peltastes interpunctatus, Quenst., sp.

Jurassic.

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Edward Forbes considered the genus *Peltastes*, Agass., to be of doubtful value, and believed that it was a section or subgenus of *Salenia*. There is much to be said in favour of this view; but it must be admitted that there is equal reason for regarding *Salenia* as a subgenus of *Peltastes*. But the species of *Peltastes* as a whole are older geologically than those of *Salenia*, and the generic distinction is the presence of a dorso-central plate in the antero-posterior axis of the apical system and of a periproct which is placed posteriorly to the dorso-central plate in *Peltastes*, and not to the right posterior, as occurs in *Salenia*. In all other important structures there is no morphological distinction to be made, although there are distinctions to be drawn regarding the ornamentation. The only satisfactory argument which can be advanced against the combination of the two types is that the species of each are numerous and definite, and that the *Peltastes* are extinct. The two groups are not connected by any intermediate species. We retain the genus *Peltastes* after indicating the very close affinity with *Salenia* and the probability of the last-named being a descendant of the first.

Genus PELTASTES, Agassiz, 1838, Monogr. des Salénies; amended in Catal. raison. Ann. des Sci. Nat. 1846 (non Desor, Synopsis, p. 145).

Test small, circular in outline, tumid at the ambitus, depressed and slightly tumid abactinally, or tall, with a part of the apical system projecting, actinally rather flatly curved. Apical system large, raised slightly, and part of it usually projecting, with large basals and small radials; a dorso-central plate small, in the long axis of the system, united to the basals 1 to 4, but not touching the basal 5, curved posteriorly for the anterior margin of the periproct. Radials large, not within the ring. Periproct posterior, bounded in front by the dorso-central plate and posteriorly and laterally by the basals 4, 5, and 1. The sutures of the disk often grooved, marked with depressions and the prolongation of the ornamentation of the basal and dorso-central plates; these plates with grooves and eminences often radiate in arrangement, margins of the basals often variously curved and notched. Ambulacra narrow, straight or slightly flexuous, with small primaries near the poriferous zone; plates low primaries only. Interradia with large primary tubercles at the ambitus, diminishing in size above and below, crenulate and usually imperforate. Peristome small, rather reentering, slightly incised.

Perignathic girdle with low broad ridges and slender unarched processes.

Distribution. Fossil: Upper Jurassic, Europe; Cretaceous, Europe and England.

There are two genera, one established by Cotteau, and the other by Desor, which can hardly be separated from *Peltastes*, namely *Pseudosalenia*, Cotteau, and *Hyposalenia*, Desor.

Pseudosalenia, Cotteau, 1859, Éch. nouv. ou peu connus, p. 22. It has the apical system projecting, non-granulate, marked with sutural impressions, with very narrow, often flexuous ambulacra, the tubercles of which are imperforate, except near the actinal surface. The dorso-central plate is in the axis of the test, and the periproct is posterior as in *Peltastes*. The figures given by Cotteau in "Note sur la famille des Salénidées," Bull. Soc. Géol. de France, 2^e sér. t. xviii. p. 622, show that the dorso-central plate is as perfect as in *Acrosalenia spinosa*, and there do not appear to have been any accessory plates. No radial enters the periproctal ring. The nature of the ambulacral plates is not known, but the perforate or imperforate condition of the tubercles is not of generic value. There really is no satisfactory distinction between this genus and the well-defined *Peltastes*, and we consider the genera to be synonymous.

Hyposalenia, Desor, 1858, Synopsis, p. 147, pl. xx. (non xix.), is synonymous with *Peltastes*, with which it was originally associated. Wright unfortunately admitted the genus and misquoted Desor. He stated, in his table of the genera of the Saleniidæ, *op. cit.* p. 228, that the vent is "excentral, posterior, and inclined to the right side." This is a mistake, and it is satisfactory to know that it was withdrawn subsequently.

The genus *Goniophorus*, Agass., 1838, Monogr. des Salénies; Desor, Synopsis, p. 146; Cotteau, Bull. Soc. Géol. de France, 2^e sér. t. xviii. p. 624 (1861), is so closely allied to *Peltastes* that there has been some discussion whether it should not be considered a subgenus of it. Cotteau, however, drew attention to deep circular depressions at the base of the ambulacral granules near the ambitus, and he noticed pores in them resembling those of the poriferous zones. He considered that these depressions were unique amongst the Echinoidea, and therefore the type remained as a genus. All the other characters of the species included under *Goniophorus* are subgeneric. There are some excellent specimens of the common species in the Museum of Practical Geology in Jermyn Street, and they

show the depressions first noticed by Cotteau. The ambulacra are very narrow, and the tubercles are small and crowded actinally; the pores are rather large, and the pairs are environed by a peripodium with a narrow linear and raised edge; the ambulacral plates are low primaries, and there are no compound plates. The depressions are deep and more or less circular in outline, and they are evidently in the line of suture between contiguous ambulacral plates; and, as the tubercles (not granules) are crowded and sometimes nearly cover the sutures, the position of the depressions is at the base of a tubercle, or where a tubercle might have been. Really the depressions are pits in the line of suture and somewhat resemble the deep groovings of the Temnopleuridæ; but there are no deep and large pits at the angles of the plates as in that family.

The pits are confined to the surface below the ambitus and get crowded near the peristome. The specimens examined by us do not show any pores on the floor of the pits, but, on the contrary, where any structure is to be seen it is of a nature indicating the appearance of the former presence of articular tubercles of sphaeridia. We consider that as the principal characters of *Peltastes* are present in the species, they must come under a subgeneric group.

Subgenus *Goniophorus*, Agassiz (genus), 1838.

Test small, swollen, subspheroidal, with large peristome, few interradial primaries, plain and crenulated. Apical system pentagonal, with five basals and five small radials ornamented with linear and raised straight keels not on the lines of the sutures; a dorso-central plate; periproct posterior to it and elongate transversely. Pits for sphaeridia large in the narrow ambulacra actinally.

Distribution. Fossil: England, Europe; Upper Greensand.

The genus *Peltastes* therefore has as its synonyms *Pseudosalenia* and *Hyposalenia*, and there is a subgenus *Goniophorus*.

Genus SALENIA.

The genus *Salenia*, Gray, Proc. Zool. Soc. Lond. 1835, p. 58, has been modified, added to, and divided by several authors, such as Desor, Cotteau, L. Agassiz, Wright, A. Agassiz, and Lovén, and contributions to the anatomy of the species of great importance have come from the last two naturalists. The recent forms have been, to a certain extent,

examined morphologically by those authors, as well as by L. Döderlein* and one of us †. A *résumé* of the different opinions regarding structure and classification is to be found in the Report on the 'Challenger' Echini, A. Agassiz, 1881, p. 50 *et seq.*, and its perusal leads at once to the belief in the necessity for an amended diagnosis of the genus.

A. Agassiz has placed the various matters under dispute so plainly and fairly, that an amended diagnosis should come from him; moreover, the knowledge now possessed of the recent forms is mainly due to him. The recent species of *Salenia* form a little group in which, with one exception (*S. Pattersoni*, A. Agassiz), there are fewer ambulacral plates than in the Cretaceous forms, and even fewer than in the Tertiary species. The radial plate no. I. is often in contact with the periproct in the recent forms, although there is some variability of this position in the same species. This entry has been noticed in Mesozoic species also, but it is not of any classificatory importance. The abruptness of the transition from the typical form of *Salenia* to the recent forms is diminished by the presence of *Salenia Blanfordi*, Dunc. and Sladen (Pal. Ind. ser. xiv. Foss. Ech. of Sind, 1881, p. 29, pl. vi. fig. 4 (Eocene)), in which the recent characters are distinctly observed, although the ambulacral plates are more numerous than in the recent *Salenia hastigerina*, A. Agass., and *S. profundus*, Dunc., for instance. *Salenia tertiaria*, Tate, is from the Miocene of Australia and belongs to the modern type. Lately, and mainly owing to the kindness of A. Agassiz in providing one of us with a specimen of the recent *Salenia Pattersoni*, A. Ag., some important additions have been made to the morphology of the genus; moreover, the examination of a very well-preserved specimen of *Salenia petalifera* from the Upper Greensand has presented some interesting structures to view for the first time. The new facts regarding the structures of these species necessitate some alteration in the generic diagnosis. The perignathic girdle of the modern form is the same as that of the ancient species, and whilst both resemble those of *Acrosalenia* and *Peltastes* they are very different from the structure seen in the Cidaridæ. In both of the above-named species there is distinct doubling of the pairs of pores, each pair in a peripodium, close to the peristome, and it is evident that demi-plates occur there. This appearance is most marked in *S. Pattersoni* and in no other recent form, but

* Döderlein, Archiv für Naturgesch. Jahrg. 51 (1885), Bd. i. pp. 73-112.

† P. Martin Duncan, Ann. & Mag. Nat. Hist. ser. 4, vol. xx. pl. ii. p. 70, pl. vii. p. 245.

it is equally visible in *Salenia petalifera*. The other fossil species do not appear to present the crowding necessary to produce the deformation. The sphaeridia discovered by one of us some years since, and the recognition of the external branchiae in the same form, *Salenia profundi*, Dunc., 1877 (Ann. & Mag. Nat. Hist. ser. 4, vol. xx. p. 245), were strong points against associating *Salenia* with the Cidaridæ, and now the presence of a perignathic girdle with ridges and processes decides the necessity for the separation, which has received the sanction of A. Agassiz.

It is well known that the dorso-central plate of the *Salenie* has an angle pointing to the suture between the basals 2 and 3, and that the periproctal ring is not posterior, but is formed at the expense of the right posterior corner of the dorso-central and of the inner edges of the basals 1 and 5. The dorso-central is in contact with basals 2, 3, 4, and in slight contact with basals 1 and 5. This is seen in *S. scutigera* and in the Eocene *S. Blanfordi*, also in *S. varispina*, in which the basals 5 and 1 are just touched, and this is also the case in *S. Pattersoni*, A. Agass. *S. hastigera* has the same arrangement.

The question of the orientation of a *Salenia*, *Peltastes*, or *Acrosalenia* need not quite depend upon the appreciation of the position of the madreporite. In a species which has given A. Agassiz and one of us some trouble, or rather a specimen of a species which Agassiz has since perfectly defined, viz. *S. varispina*, there were two basals perforated by the madreporic body. The result of placing the madreporite seen by one observer as a body in the right anterior basal (no. 2) was to throw the anus posterior to the dorso-central plate, and to suggest that the form was more Peltastic than Salenian. But A. Agassiz, selecting the other basal (no. 1), which was also perforated, came to the inevitable conclusion that the species had the anus excentric behind and to the right hand, that is to say it was a *Salenia* *. It is not uncommon to find the genital duct opening so large and ragged in more than one basal in fossil forms that the simulation of the ragged opening of the madreporite is perfect. Under the circumstances the opportunities of making mistakes are at hand, and it may be impossible to settle which basal is no. 2, so as to place radial III. in front, and proceed to determine the antero-posterior axis of the apical system.

Often no trace of a madreporite can be seen. Under such difficulties the method of Lovén of distinguishing the oblique

* Revision, pl. iii. figs. 9 & 11; also Report on 'Blake' Echini.

actinal axis may be used, after discovering by his method which is interradium 3 actinally (Lovén, 'Études,' p. 47).

The periproctal ring of *Salenia* is formed by the basals and the dorso-central plate in the majority of species and in many specimens of some species; but a radial plate may come in, and it is the radial I. which thus occasionally enters. Usually there is an elevated ridge at the edge of the ring, which is caused by an upward growth of that part of the plates. There may be granules or stunted sessile spines, or even small spines on the ring, or it may be plain. The inner edge of the ring gives attachment to the periproctal membrane, and this is penetrated more or less centrally by the anal tube. A series of plates, few in number in the young and more numerous in older specimens, covers the membrane, and usually the plates are in irregular circles around the anus, or the plates may radiate from the ring to the anus and become smaller and more numerous with age. The plates may carry spinules or small knobs.

The number of the primary ambulacral tubercles varies with the species, and so does the closeness of the two vertical rows in which they are arranged; the granulation between the rows differs also in extent and amount. The number of primary plates of the ambulacra is greater in the Mesozoic species than in the Tertiary and recent, except in *S. Pattersoni*, A. Ag., in which the primaries are so crowded that there is doubling of the pairs of pores near the peristome. It is the case that the later *Saleniæ* can be classified in a little group by themselves in the genus.

There is great diversity in the ornamentation of the basals, radials, and dorso-central plate in the species of *Salenia*, and while it is of a radiating and grooved character in some species it is almost plain in others; there may be almost a perfect resemblance to the ornamentation of *Marsupites*, or there may be but a slight radiation of furrows and ridges amongst the other ornamentation, or only spinules may exist fixed without knobs. The sutures of the plates may be just visible, but usually they are distinct and often pitted, and the ornamentation has some reference to the spaces between the shallow pits. Pedicellariæ occur on the apical system and elsewhere.

Genus SALENIA, Gray, 1835, amended.

Test small, subglobose or depressed. Apical system larger than the peristome, more or less raised. The dorso-central plate more or less geometrical, imperfect, and eroded at the right posterior angle by the periproctal ring, in contact with all the

basals. Radial plates large, with the pore in the adoral edge; one plate may or may not enter the periproctal ring. Periproct large, with a plated membrane pierced by the anal opening. Ambulacra narrow, with two rows of primary tubercles; plates all simple primaries; crowding rare near the peristome; when it occurs there are demi-plates. Interradia with large primaries. Peristome with cuts for the external branchiæ, with a membrane plated or not. Perignathic girdle with broad ridges and slender ununited processes; jaws with the opening of the pyramid unarched; teeth with a keel. Spines of primaries long, slender, variable in ornamentation; small spines club-, wedge-shaped, and flat. Sphæridia exist.

Fossil: Cretaceous, England, Europe, Asia, North Africa; Eocene, Europe, Asia; Miocene, Australia.

Recent: Caribbean Sea, both of the great oceans, Japanese Sea. Depth from 60 to 1700 fathoms.

It will have been remarked that nothing is said in this diagnosis about ornamentation of the apical plates, or about the crenulation and condition, whether smooth or not, of the mamelons of the primary tubercles. The ornamentation is that of the family, and the perforation or non-perforation of the tubercles, of all which are crenulated, is not of generic importance when the subgenus *Heterosalenia* is considered. The imperforate condition is typical of the true species of *Salenia*; and the only distinction between Cotteau's *Heterosalenia* and these is a perforate condition of the primaries in the last-named genus, or rather doubtful subgenus, which has but one species in the Hippurite Chalk of Martigues.

The forms which have been considered in this communication evidently belong to a family which is separable from the Cidaridæ on the one hand, and the Diadematidæ, Arbaciidæ, Triplechinidæ, and all other regular Echinoidea on the other.

Family Saleniidæ.

Regular endocyclic gnathostomes, with a persistent dorso-central plate. A periproct posterior, directly or partly to the right of the dorso-central plate, with a plated membrane, which gives passage to an anal aperture. Ambulacral plates either primaries or compound primaries. Perignathic girdle with ridges and processes. Branchiæ external.

Genus ACROSALENIA, Agass., 1840, amended.

Syn. *Pseudosalenia*, Cott.

Genus PELTASTES, Agass., 1838, amended.

Syn. *Hyposalenia*, Desor.

Subgenus GONIOPHORUS, Agass., 1838.

Genus SALENIA, Gray, 1835, amended.

Subgenus HETEROSALENIA, Cott., 1861.

XVI.—*On the Pelagic Fauna of our Shores in its Relation to the Nourishment of the Young Food-Fishes.* By Prof. M'INTOSH, M.D., LL.D., F.R.S., &c.*

BY the term pelagic fauna is meant the inhabitants of the whole body of the water from the surface to the bottom. This immense area, it is well known, varies greatly in depth, viz. from 4655 fathoms (that is upwards of five miles), as sounded by the American exploring-ship 'Tuscarora,' near the Kurile Islands in the North-east Pacific, to a few inches, as on gently sloping sandy beaches.

The pelagic fauna of the surface of the ocean has for ages attracted the attention both of voyagers and of scientific men. In the tropical and subtropical regions especially the abundance and variety of such animals are remarkable; yet they are not confined to these warmer areas, certain types, as copepods and pteropods, occurring in such countless multitudes in the arctic seas that they form the food of the right whales. The colder waters, just mentioned, however, do not, as a rule, present the brightly coloured and conspicuous swimmers of the warmer areas, such as Portuguese Men-of-war, Venus's Girdles, the exquisite siphonophores, pelagic annelids (e. g. *Alciopa*), and certain types of pteropods and crustaceans.

In our own seas, even the most superficial observer on the eastern coast must have been struck by the great beauty and abundance of the lilac *Aurelia*, the deep purple of the young or the rich brown of the adult *Cyanea*, frequently stranded in multitudes on sandy beaches in autumn; while in the milder waters off the western shores the greater variety of the purple and reddish medusæ (e. g. *Pelagia*, *Æquorea*, *Modeeria*, *Oceania*), the occasional occurrence of such truly oceanic forms as *Physalia*, *Verella*, and *Ianthina*, the long chains of Salpæ, and the crystalline calices and orange polypites of

* Abstract of Introductory Lecture to the Class of Natural History, University of St. Andrews, November 13, 1886.